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Complete List of Authors:	Cha, Eun Shil; Korea University College of Medicine, Chang, Shu-Sen; National Taiwan University, Gunnell, D; University of Bristol, Department of Social Medicine Eddleston, Michael; University of Edinburgh, Clinical Pharmacology Unit Khang, Young-Ho; Seoul National University College of Medicine, Department of Health Policy and Management Lee, Won Jin; Korea University, Preventice Medicine
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Impact of paraquat regulation on suicide in South Korea

Eun Shil Cha[1], Shu-Sen Chang[2], David Gunnell[3,4], Michael Eddleston[4,5], Young-Ho Khang[6], Won Jin Lee[1*]

[1]Department of Preventive Medicine, Korea University College of Medicine

[2]Institute of Health Behaviors and Community Sciences, and Department of Public Health, College of Public Health, National Taiwan University

[3]School of Social and Community Medicine, University of Bristol

[4]South Asian Clinical Toxicology Research Collaboration, Faculty of Medicine, University of Peradeniya, Sri Lanka

[5]Pharmacology, Toxicology & Therapeutics, University/BHF Centre for Cardiovascular Science, University of Edinburgh

[6]Department of Health Policy and Management, Seoul National University College of Medicine, and Institute of Health Policy and Management, Seoul National University Medical Research Center

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[*]**Correspondence to:**

Won Jin Lee, MD, MPH, PhD.

Department of Preventive Medicine, Korea University College of Medicine, Seoul 136-705, South Korea.

Email: leewj@korea.ac.kr

Phone: +82-2-2286-1413; Fax: +82-2-927-7220

Abstract

Background Ingestion of pesticides (mainly paraquat) accounted for one fifth of suicides in South Korea in 2006-2010. We investigated the effect on suicide mortality of regulatory action, culminating in a ban on paraquat in South Korea in 2011-2012.

Methods We calculated age-standardized method-specific suicide mortality rates among people aged ≥15 in South Korea (1983-2013) using registered death data. Negative binomial regression was used to estimate changes in the rate and number of pesticide suicides in 2013, compared to those expected based on previous trends (2003-2011).

Results Pesticide suicide mortality halved from 5.26 to 2.67 per 100 000 population between 2011 and 2013. Compared with the number expected based on previous trends, the regulations were followed by an estimated 847 (95% confidence interval [CI] -1180 to -533) fewer pesticide suicides, a 37% reduction in rates (rate ratio=0.63, 95% CI 0.55 to 0.73) in 2013. The decline in pesticide suicides after the regulations was seen in all age/gender/geographic groups. The absolute reduction in the number of suicides was greatest among men, the elderly, and in rural areas. The reduction in pesticide suicides contributed to 56% of the decline in overall suicides that occurred between 2011 and 2013. There was no impact of the regulations on crop yield.

Conclusions The regulation of paraquat in South Korea in 2011-2012 was associated with a reduction in pesticide suicide. Further legislative interventions to prevent the easy availability of highly lethal suicide methods are recommended for reducing the number of suicides worldwide.

Key words: Death, Intentional poisoning, Intervention, Legislation, Pesticides

Key Messages

- Restricting access to toxic pesticides can reduce the suicide rate from pesticides and from all methods.

- The absolute reduction in pesticide suicide mortality rates was greatest among men, the elderly, and people living in rural areas.

- In countries where pesticides are commonly used as a method of suicide, legislative bans on the most toxic products are likely to reduce overall suicide rates.

Introduction

Suicide mortality from pesticide poisoning is an important public health issue around the world, with an estimated 258 000-372 000 people dying following pesticide ingestion every year (1). In 2012, South Korea had the highest suicide mortality rate (29.1 per 100 000 population) among all Organization of Economic Cooperation and Development (OECD) member countries (2) and a relatively large proportion of suicides from pesticide poisoning compared with other countries in general (3) as well as compared to other industrialized Asian countries such as Japan and Taiwan (4,5). Suicide using pesticides accounted for 21% of all suicides in South Korea between 2006 and 2010 (6).

A variety of approaches, ranging from legislative regulation to improving the management of patients who have ingested pesticides, have been applied to reducing the number of pesticide suicides (7). Among them, pesticide regulation is recommended as the most important and effective method for reducing the number of suicides (8), since intentional self-poisoning is often impulsive and facilitated by the easy availability of pesticides (9,10). However, only a few studies have been conducted to evaluate the effect of pesticide regulation on suicide worldwide. In Sri Lanka, restrictions on the import and sales of World Health Organization (WHO) Class I toxicity pesticides in 1995 and endosulfan in 1998 were followed by reductions in suicide rates (11), and a partial ban of insecticides (i.e., dimethoate and fenthion) caused a large reduction in admissions from poisoning by these compounds in the Polonnaruwa District (12). There have also been reports of a decline in the suicide rate following decreased imports of paraquat in Samoa (13) and after discontinuation of paraquat production in Japan (14). By contrast, a range of regulations to restrict access to pesticides which did not include those pesticides causing most pesticide-related mortality did not appear to influence the incidence of pesticide suicides in Taiwan (15).

In South Korea, since the Pesticide Management Act of 1957, a number of pesticide regulations have been implemented (http://www.rda.go.kr). Paraquat (1,1’-dimethyl-4,4’-bipyridinium dichloride), a non-selective herbicide, has been identified as the most important agent used in self-poisoning episodes seen in emergency departments in South Korea (16) as well as a study of occupational poisoning cases (17). The South Korean government implemented a paraquat management plan in 1999 and revised it in 2005 (http://www.rda.go.kr) in an attempt to combat paraquat self-poisoning. However, as mortality from paraquat poisoning remained high after 2005, South Korea cancelled the re-registration of paraquat from the end of November in 2011 and banned its sale from the end of October in 2012.

The objectives of this study were to investigate the effect of these paraquat regulations on suicide and crop yields and to identify the populations most affected with the aim of informing strategies for suicide prevention. Identifying the effect of paraquat regulation on the suicide rate may have important implications for the reduction of the global burden of suicide.

Methods

Suicide and poisoning data

South Korean suicide mortality data for 1983-2013 were obtained from Statistics Korea (http://kostat.go.kr). The registered death data include information on age, gender, area of residence, and date of death. Underlying causes of death are coded in the data according to the *International Classification of Diseases, 10th Revision* (ICD-10) (18).

Suicide by pesticide poisoning was defined as those cases featuring the ICD-10 code X68. Among suicides due to pesticide poisoning, ICD-10 T codes were used to identify the specific category of agents including insecticides (T60.0-T60.2), herbicides and fungicides (T60.3), rodenticides and other pesticides (T60.4, T60.8), and unspecified pesticides (T60.9). In addition, suicide deaths from poisoning using medicinal/biological substances (T36-T50), alcohol, organic solvents, and corrosive substances (T51-T57), carbon monoxide and other gases (T58-T59), and other and unspecified chemicals (T61-T65) were extracted to enable comparisons with pesticide suicide trends.

Age-specific effects were investigated by analyzing data for people aged 15-49, 50-59, 60-69, and 70+ years old separately; these groups were chosen as trends in pesticide suicide within these age-bands were similar. Based on the administrative residential districts provided in the death data, urbanization levels were identified. Metropolises included the capital city, Seoul, and six other major cities. Small- and medium-size cities and rural areas were determined by governmental administrative divisions where population sizes and rural characteristics are considered.

National Emergency Department Information System data for 2006-2013 were obtained through the National Emergency Medical Center (http://www.nemc.or.kr) to assess trends in non-fatal poisoning by pesticide and other types of poisoning. This system was developed in 2004 and the non-fatal poisoning data were available from 2006. The coverage of this data source increased from 13.6% of all visits to South Korean emergency departments in 2006 to 49.2% in 2013. The National Emergency Department data are coded using ICD-10; only the primary diagnostic code was used in this study. The same ICD-10 codes (T60.0-T60.9) used in our analysis of mortality data were used to identify the types of pesticide (i.e., insecticides, herbicides etc.) presenting to emergency departments.

Pesticides and other related variables

To assess whether there were changes in the overall amount of pesticides used in South Korea, data for the quantity and active ingredients of agricultural pesticides were extracted from the annual Agrochemical Year Books, published by the Korea Crop Protection Association (19). These data were based on reports from all the companies that produce pesticides or import and synthesize related raw materials. The data for the proportion of people involved in farming were obtained from the agricultural census conducted every 5 years (http://kostat.go.kr) and refers to the proportion of the population belonging to households that were involved in farming, and estimated values for other years in the period were based on linear interpolation. The information on regulated pesticides such as active ingredient, date of ban, and chemical category was obtained from the Korea Rural Development Administration (http://www.rda.go.kr), historical documents (20) published by the Korea Crop Protection Association, and by searching on the Internet. Data on agricultural crop yields were obtained from annual Agricultural Production Surveys conducted by

Statistics Korea. Altogether 57 pesticides were banned between 1983-2013; however, the majority of the bans on highly toxic pesticides occurred after 2008, including the cancellation of paraquat re-registration in 2011 (Supplementary Table 1S). However, in the same year (2011) the re-registrations of eight insecticides were also cancelled. The information on potential risk factors for suicide, such as levels of unemployment, divorce rate, and prevalence of alcohol drinking were also collected from Statistics Korea.

Data analysis

In the analysis, the main outcome of interest was change in the incidence of pesticide suicide mortality (i.e., pesticide suicide) following the paraquat regulations. In keeping with ICD codes (T60 and X68) we defined pesticides as herbicides and fungicides, insecticides, rodenticides and other pesticides, unspecified pesticides. The exposure was South Korea's regulatory action to restrict the availability of paraquat in 2011-2012. We also examined the following secondary outcomes: i) changes in suicide mortality from self-poisoning by specific types of pesticide (i.e., herbicides, insecticides, other pesticides, unspecified pesticides) to investigate the specific effect of the paraquat ban; in South Korea, the majority of deaths from herbicide poisoning were due to paraquat (16); ii) changes in overall (all methods combined) suicide rates; and iii) trends in suicide rates using methods other than pesticides to investigate possible substitution effects.

Rates of suicide mortality and non-fatal poisoning were directly standardized in 5-year age groups, using the 2000 World Standard Population (21) as the standard population. Mid-year populations of registered residents by gender, 5-year age groups, and the administrative districts for each year were obtained from Statistics Korea and used as denominators. Age-standardized rates of suicide per 100 000 were calculated among the population aged 15 and over. To examine regional differences in the contribution of pesticide suicide mortality to overall reduction in suicide between 2011 and 2013, absolute and relative changes in the rates of overall suicide, pesticide suicide, and non-pesticide suicide by urbanization level (metropolis, small- and medium-size city, and rural) were calculated and compared. National estimates for emergency department visits for pesticide poisoning were calculated using the sampling weights as the inverse of the coverage proportion of the National Emergency Department Information System by location of hospital and calendar year as in a previous study (22). The case fatality for pesticide poisoning and non-pesticide poisoning was also calculated as the proportion of deaths among non-fatal poisoning cases.

To estimate changes in trends in pesticide suicide mortality and reduction in deaths by suicide following the pesticide regulation, the year of 2003 was chosen as the starting year of the study period based on the results of Joinpoint regression analysis (http://surveillance.cancer.gov/joinpoint), which showed that trend in pesticide suicide changed from an upward trend to a linear downward trend in 2003 (Supplementary Table 2S). Negative binomial regression was used to estimate rate ratios (and the change in the number of suicides) in 2013 compared with suicide rates based on linear trends before the paraquat regulation (2003-2011). The study period from 2003 to 2013 provided 11 time points in this analysis. There was statistical evidence for overdispersion in the Poisson regression models and therefore negative binomial regression models were used. A similar approach has been used in other studies to estimate changes in suicide rates following the 2008 Great Recession (23) and firearm regulation in Australia (24). When estimating the negative binomial regression models we included gender, age group (15 categories starting from age 15-19 up to age ≥85), and an offset term log (population by year, gender, and age group) to adjust for annual changes in population figures and age structure; calendar year was also included in the model to adjust for time trend. The effect of paraquat regulations was investigated by including two dummy variables in the negative binomial regression models, one for 2012 and one for 2013, and we focused on the results for 2013 (i.e., the first complete post-regulation year). Rate ratios were estimated using negative binomial regression analysis, and when estimating their confidence intervals the model accounted for the variance for both observed and expected numbers of suicides given pre-2011 linear trends. The expected number of suicide and its 95% confidence intervals in 2013 were calculated using the actual number of suicide divided by the rate ratio and its confidence intervals. The reduced number of suicides in 2013 was calculated as the difference between the actual number of suicides and that expected number. To investigate whether the impact varied in different groups, analyses stratified by gender, age, urbanization level, suicide method, and season were conducted; differences between groups were also formally tested by including appropriate interaction terms in the negative binomial regression models.

Three sensitivity analyses were performed to check the robustness of the results: i) the start year of the period used to estimate trends in suicide prior to the paraquat bans was changed from 2003 to 2002 or 2004; ii) an interrupted time series approach (using 2011 as the intervention year) (25) was used although it is recommended that at least 12 data points both before and after the intervention are optimal if this approach is considered, whereas our analysis was based on only nine time points (2003-2011) before the regulations and two time points (2012 and 2013) subsequently; and iii) a non-linear trend in suicide rates was assumed by including a quadratic term of calendar year in the negative binomial model. All analyses were performed using Stata 13.0 (StataCorp, College Station, Texas).

Ethics approval

We used publicly available data for mortality and emergency department visits without any personal identifiers, and thus ethical approval was unnecessary.

Results

The age-standardized rates of pesticide suicide mortality was relatively stable from 1983 until 2001, but rapidly increased thereafter, and peaked of 9.2 per 100 000 in 2004 (Figure 1a); it then decreased gradually afterwards. The decline between 2011 (the year the paraquat regulations were introduced) and 2013 was 49.2%, showing a greater reduction in 2013 than that expected based on trend between 2003 and 2011 (Figure 1b). Overall trends in pesticide suicide mortality did not appear to be associated with either trends in pesticide usage or the proportion of people belonging to households involved in farming (Figure 1a). Agricultural crop yields increased slightly over the study period and the results were similar for specific types of crops (Supplementary Figure 1S). In addition, changes in levels of unemployment, prevalence of alcohol drinking, and divorce rate were not associated with the trends of pesticide suicides (data not shown).

In 2013, the overall pesticide suicide mortality rate was lower (rate ratio=0.63, 95% confidence interval [CI] 0.55 to 0.73) than expected based on previous trends (2003-2011) with an estimated 847 (95% CI -1180 to -533) fewer suicides (Table 1). More reduced suicide cases were expected when we included the cases of undetermined intend deaths (Y18) as a pesticide suicide cases (estimated reduction in the number of pesticide suicides = 1031; a 39% fall). The reduction in pesticide suicide rate, indicated by rate ratios, was similar in men and women, all age groups, and all areas (all p for interaction >0.10), while the absolute reduction in pesticide suicide mortality was greater among men, the elderly, and people living in rural areas. The largest reduction was found in rural areas (45%); smaller reductions were seen on metropolises (39%) and city areas (30%), although statistical evidence for difference between area in the magnitude of the reduction was limited (p for interaction = 0.14). Suicides from herbicide poisoning showed the largest reduction compared to other types of pesticide (p for interaction <0.001). There was no evidence of a rise in suicides using other (non-herbicide) pesticides.

Results from sensitivity analyses were similar or even showed a higher estimate of reduction in pesticide suicides. When using 2002 or 2004 as the starting year for the pre-2011 trend, the estimated reductions in suicide were similar to or higher than those in the main analysis based on 2003-2011 trends (Supplementary Table 3S). When we used an interrupted time series model to estimate the impact of the paraquat regulations our findings were also similar (estimated reduction in the number of pesticide suicides = 891; a 38% fall). Models accounting for a non-linear trend by including a quadratic term of calendar year also showed similar findings.

The reduction in pesticide suicide of 2.59 per 100 000 (see Table 2) contributed to 56% (2.59/4.64) of the reduction in overall suicide (by 4.64 per 100 000) in South Korea between 2011 and 2013. The contribution of falls in pesticide suicides to reductions in overall suicide rates was greater in rural areas (7.05/7.75=91.0%) than small- and medium-size cities (2.77/4.76=58.2%) and metropolises (1.07/3.80=28.2%) (Table 2). However, the relative changes in pesticide suicide rates were similar across urbanization levels.

The overall rate of suicide from all pesticide categories decreased between 2003-2013 regardless of the type of product (i.e., insecticide, herbicide etc.), but the reduction was most pronounced for herbicides after 2011 (Figure 2a). By contrast, there were increasing trends in suicide by medicine and carbon monoxide and other gases from 2008. The number of non-fatal cases of non-pesticide poisoning showed an increasing trend between 2006-2013, whereas the incidence of non-fatal pesticide poisoning peaked in 2010 and subsequently fell

(Figure 2b). The case fatality proportions for pesticide poisoning also declined after 2011, the year of the paraquat ban; the reduction was mostly attributable to the decrease in case fatality for herbicides rather than insecticides or other poisons (Figure 2c). When we recalculated case fatality based on intentional poisoning cases although there are some missing values for the information of intentionality, the results were broadly similar (Supplementary Figure 2S).

Discussion

Our results indicate that the cancellation of the re-registration, and then the ban of the herbicide paraquat was associated with a marked reduction in the number of suicides from pesticide poisoning in South Korea. This reduction was observed for all groups, although the absolute effect size appeared to be greatest in men, the elderly, and people living in rural areas. Of note, suicide deaths involving herbicide poisoning showed the largest reduction compared to other types of pesticide, indicating the specific effect of paraquat ban. However, we could only investigate short-term effects (i.e., two years follow-up); further research including data for more years is needed to investigate longer term effects of the pesticide regulation and any possible method substitution. Pesticide poisoning is still a common suicide method worldwide; therefore, pesticide restriction by legislative regulation may have considerable impacts on the overall burden of suicide not only in South Korea, but also in other countries where pesticide poisoning is prevalent.

Our finding adds evidence that means restriction of pesticides can reduce the suicide rate from pesticides and from all methods particularly in rural areas. Legislative control reducing pesticide availability is potentially an important and effective method to combat pesticide suicide because pesticides have been found to have been chosen principally on the basis of availability in Sri Lanka (26), India (27), China (28), and South Korea (29). Previous studies in South Korea also support that, according to the analysis of demographic, regional and seasonal variations in pesticide poisoning (6,30), the high rate of pesticide ingestion for suicide may be explained by their accessibility. There is strong evidence that restricting access to specific methods can lower overall suicide rates (31,32), our results support the view that pesticide restriction could lead to a reduction in the global burden of suicide (8,11).

Our findings are consistent with those from other studies in Sri Lanka (11), Samoa (13), and Japan (14) which showed that pesticide regulation led to a fall in the incidence of suicide.

Although a variety of pesticide regulations have been implemented in South Korea since the 1980s, the earlier bans did not appear to have a meaningful impact on suicide. This is likely to be because they did not include pesticides (such as paraquat) that accounted for the majority of deaths. Similarly, bans on pesticide products in Taiwan showed no clear evidence of a beneficial effect when they did not include the pesticides accounting for the most deaths (15). Although banning entails multiple difficulties, and effective restriction may be more appropriate as a public approach than outright bans (33), paraquat was not controlled effectively by regulatory efforts in 1999 and 2005 in South Korea. In addition, although there were some concerns about paraquat bans may adversely affect agricultural output, our results provide evidence that crop yield was not affected by the paraquat ban, which is consistent with findings in Sri Lanka (34). Many thousands of deaths in South Korea might have been prevented by an earlier ban on paraquat. Therefore, when applying pesticide regulation, selecting important substances in a timely manner should be emphasized.

It is possible that the decline observed in this study results from a combination of the regulation of other pesticides with the ban on paraquat. In 2011, the Rural Development Administration led the voluntary withdrawal by the pesticide industry of a number of compounds that were often associated in emergency rooms with pesticide poisoning (Figure 1a, Supplementary Table 1S) (16). However, as these were mostly organophosphates or carbamate insecticides, this cannot account for the reduction in deaths from herbicides and fungicides, most of which are caused by paraquat. Paraquat was the only herbicide to be affected by regulatory action in 2011. Since organophosphate or pyrethroid pesticides have a relatively lower case fatality and contribute to a smaller proportion of poisoning cases than paraquat (16), their regulation would not be expected contribute as much to the reduction in mortality. Therefore, our findings support the hypothesis that the reduced suicide rate from pesticide poisoning in 2013 was mainly the effect of the paraquat regulation.

Trends in suicide may be influenced by changing levels of economic growth, unemployment, and divorce in South Korea (35). From 2011 to 2013, levels of unemployment, divorce, and alcohol consumption decreased or were unchanged. These may have contributed to the decrease in overall suicide rate after 2011; however, the decline in pesticide suicides was proportionately much greater than that for suicides using other methods, indicating a regulation-specific effect. The shrinking size of the farming population, with its easy access to pesticides, and the reduction in pesticide sales may also contribute to the gradual decrease in pesticide deaths. However, such gradual changes are unlikely to explain the marked fall in suicide rate from pesticides between 2011 and 2013.

Substitution of methods may have occurred. Increases in suicide by medicinal poisoning and carbon monoxide and other gases occurred around the same time as the declines in pesticide suicide. A shift towards medicinal drugs (36) and less toxic pesticides that have not been banned (33), from pesticide poisoning was observed in Sri Lanka although these did not counter-act (and were smaller than) the overall reduction in suicide. However, our study showed a decrease in non-pesticide suicide as well as pesticide suicide after 2011 (Figure 1a). This suggests that any substitution from pesticide poisoning to other methods was limited. Previously, no method substitution was reported along with the reduction in poisoning suicide rates in Taiwan (37).

We found that the absolute effect size of decreased pesticide suicide rates was greater among men, the elderly, and people living in rural areas, which may be explained by the fact that these are the most vulnerable populations for pesticide poisoning in South Korea (6,30). Therefore, pesticide control interventions for suicide prevention would have particular significance for these groups in South Korea, although the effect would appear as an overall reduction across all groups. Gender- and age-specific trends in pesticide suicide change were similar in Taiwan where the elderly living in rural areas showed the highest rate of pesticide suicide (15).

The validity of the coding of suicide cases is a potential concern in our study. However, in South Korea, unnatural deaths are investigated by the National Police Agency, and this agency regularly reports all death cases to Statistics Korea (38). Statistics Korea combines the data from the reported physician's death certificate and the National Police Agency to complete a final dataset. Vague or missing causes of death which might be recorded on the physician's death certificate are corrected or updated with information provided by the National Police Agency data or other sources, such as National Institute of Scientific Investigation data or military data. Furthermore, the proportion of unspecified agents among pesticide poisoning has decreased in recent years, indicating that recent downward trends in suicides that involved herbicides are likely to under-estimate the true extent of the decline in paraquat related suicides.

The other limitation is that there is no direct information in the national mortality statistics that paraquat was the cause of death other than the T60.3 code, which indicates that the death was caused by a herbicide or fungicide. However previous research suggests that paraquat was the most commonly used agent in episodes of pesticide self-poisoning in South Korea (16). In addition, there may be no material effect of such lack of direct information on paraquat on time trends in suicide and poisoning, since no significant coding change in the death and admission data system has occurred during the 2000s.

In conclusion, our findings suggest that South Korea's ban on paraquat sales have resulted in a reduction in suicide mortality rates with the largest decreases occurring amongst men, the elderly, and people living in rural areas. Although we cannot completely rule out the impacts of other unrecognized factors in affecting suicide rates, no other specific reasons are likely to explain the sharp decline in pesticide suicide seen in the two years after the regulation. Since the number of pesticide suicide deaths remains substantial in South Korea (1442 pesticide suicides in 2013), further pesticide regulations may substantially reduce the number of suicides. Furthermore, because suicide is an important public health issue and pesticides are one of the most frequently used methods of suicide worldwide, more intensive intervention efforts to reduce pesticide self-poising deaths by means restriction through legislative control are urgently needed to save lives.

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Declaration of interests

DG has been a member of a) the scientific advisory group of a Syngenta-funded study to assess the toxicity of a new formulation of paraquat; b) the scientific advisory group for a pesticide safe storage project funded by Syngenta; c) chair of a DMEC for a Syngenta-funded trial of the medical management of paraquat poisoning (2003-2011). He received travel costs to attend research group meetings. He was an Expert Advisor to WHO's First Consultation on Best Practices on Community Action for safer access to pesticides, Geneva (2006).

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Table 1. Rate ratios and change in number of pesticide suicides in 2013 relative to those expected based on trend 2003-2011 by selected characteristics

Characteristics	Rate ratio[a] (95% CI[b])	Change in number of pesticide suicides (95% CI)	p for interaction
Total	0.63 (0.55, 0.73)	-847 (-1180, -533)	
Gender			
Male	0.62 (0.53, 0.74)	-599 (-867, -344)	0.937
Female	0.64 (0.54, 0.76)	-261 (-395, -147)	
Age group			
15-49	0.52 (0.42, 0.65)	-156 (-233, -91)	0.712
50-59	0.61 (0.50, 0.74)	-157 (-245, -86)	
60-69	0.50 (0.42, 0.59)	-260 (-359, -181)	
≥ 70	0.58 (0.51, 0.66)	-628 (-738, -396)	
Area			
Metropolis	0.61 (0.51, 0.74)	-139 (-209, -77)	0.139
Small- and medium-size city	0.70 (0.61, 0.80)	-327 (-487, -191)	
Rural	0.55 (0.47, 0.64)	-378 (-521, -260)	
Causative agents			
Herbicides and fungicides (T60.3)	0.53 (0.46, 0.61)	-791 (-1047, -570)	<0.001
Insecticides (T60.0-T60.2)	0.68 (0.55, 0.84)	-113 (-196, -46)	
Rodenticides and others (T60.4, T60.8)	1.34 (0.84, 2.14)	7 (-6, 15)	
Unspecified (T60.9)	0.94 (0.80, 1.12)	-18 (-70, 30)	
Season			
Spring (March-May)	0.66 (0.57, 0.76)	-233 (-341, -143)	0.938
Summer (June-August)	0.58 (0.49, 0.68)	-306 (-439, -199)	
Fall (September-November)	0.61 (0.51, 0.72)	-196 (-295, -119)	
Winter (December-February)	0.65 (0.55, 0.78)	-141 (-214, -74)	

[a]Adjusted for age, gender and calendar year

[b]Confidence Interval

Table 2. Differences of age-standardized mortality rates per 100 000 for overall suicides, pesticide suicide, and non-pesticide suicide by urbanization level between 2011 and 2013

	2011		2013		Absolute rate difference	Relative rate change (%)
	N (%)	Rate	N (%)	Rate		
Overall						
All suicides	15 850 (100)	34.90	14 389 (100)	30.26	-4.64	-13.3
Pesticides	2580 (16.3)	5.26	1442 (10.0)	2.67	-2.59	-49.2
Non-pesticide	13 270 (83.7)	29.64	12 947 (90.0)	27.59	-2.05	-6.9
Rural						
All suicides	2139 (100)	41.79	1682 (100)	34.04	-7.75	-18.5
Pesticides	897 (41.9)	13.36	462 (27.5)	6.31	-7.05	-52.8
Non-pesticide	1242 (58.1)	28.43	1220 (72.5)	27.73	-0.70	-2.5
Small- and medium-size city						
All suicides	7316 (100)	36.14	6800 (100)	31.38	-4.76	-13.2
Pesticides	1265 (17.3)	5.96	762 (11.2)	3.19	-2.77	-46.5
Non-pesticide	6051 (82.7)	30.18	6038 (88.8)	28.19	-1.99	-6.6
Metropolis						
All suicides	6395 (100)	32.21	5907 (100)	28.41	-3.80	-11.8
Pesticides	418 (6.5)	2.04	218 (3.7)	0.97	-1.07	-52.5
Non-pesticide	5977 (93.5)	30.17	5689 (96.3)	27.44	-2.73	-9.0

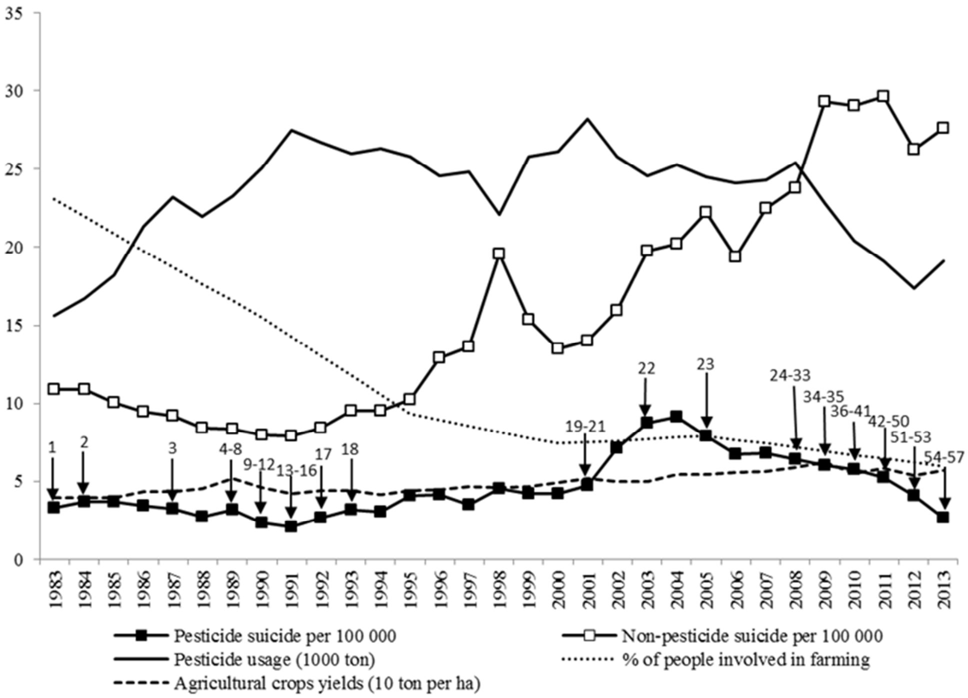
Figure legends

Figure 1. (a) Age-standardized mortality rate of pesticide suicide, non-pesticide suicide, usage of pesticide, % of the population of people belonging to households involved in farming, and agricultural crop yields in South Korea, 1983-2013 (arrows indicate the years when bans became effective for specific pesticides (Supplementary Table 1S)), (b) Age-standardized mortality rate of pesticide suicide in 2003-2013 with the predicted line based on trend 2003-2011

Figure 2. (a) Age-standardized poisoning suicide mortality rate per 100 000 by causative agents, 2003-2013, (b) age-standardized non-fatal poisoning rate by causative agents and (c) case fatality proportion for pesticide and non-pesticide poisoning in South Korea, 2006-2013

Figure 1

(a)


35
30
25
20
15
10
5
0
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
1
2
3
4-8
9-12
13-16
17
18
19-21
22
23
24-33
34-35
36-41
42-50
51-53
54-57
Pesticide suicide per 100 000
Non-pesticide suicide per 100 000
Pesticide usage (1000 ton)
% of people involved in farming
Agricultural crops yields (10 ton per ha)

(b)

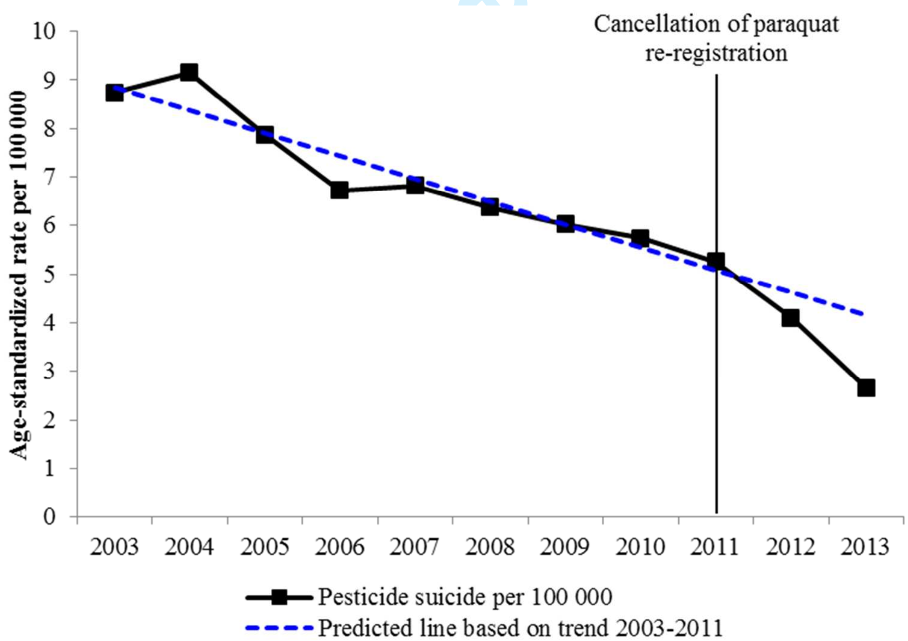
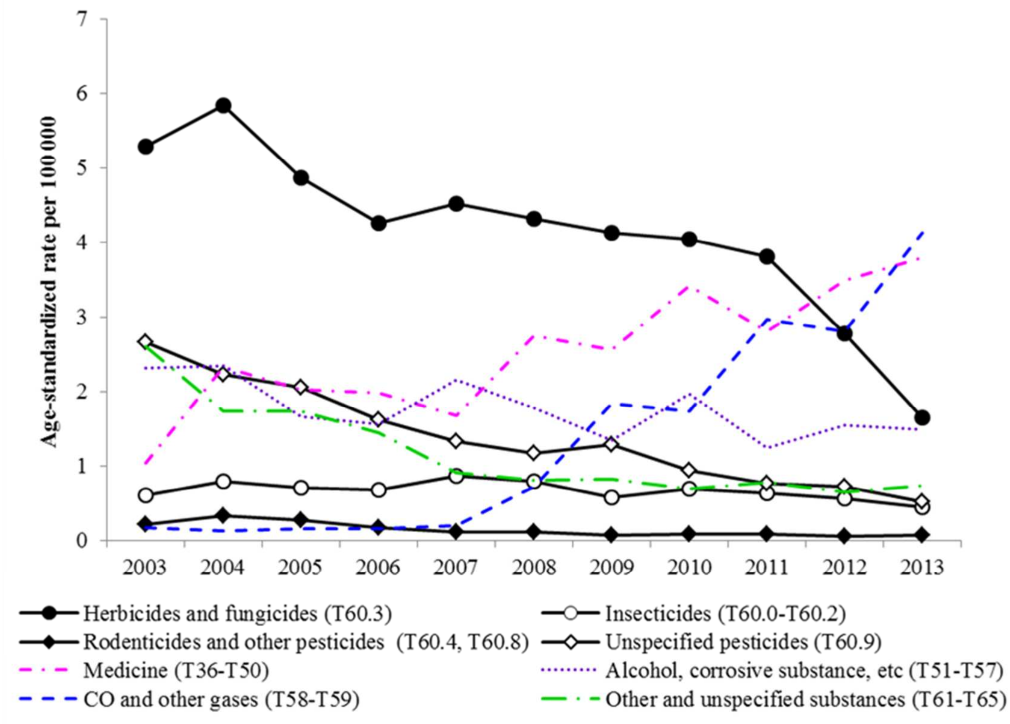
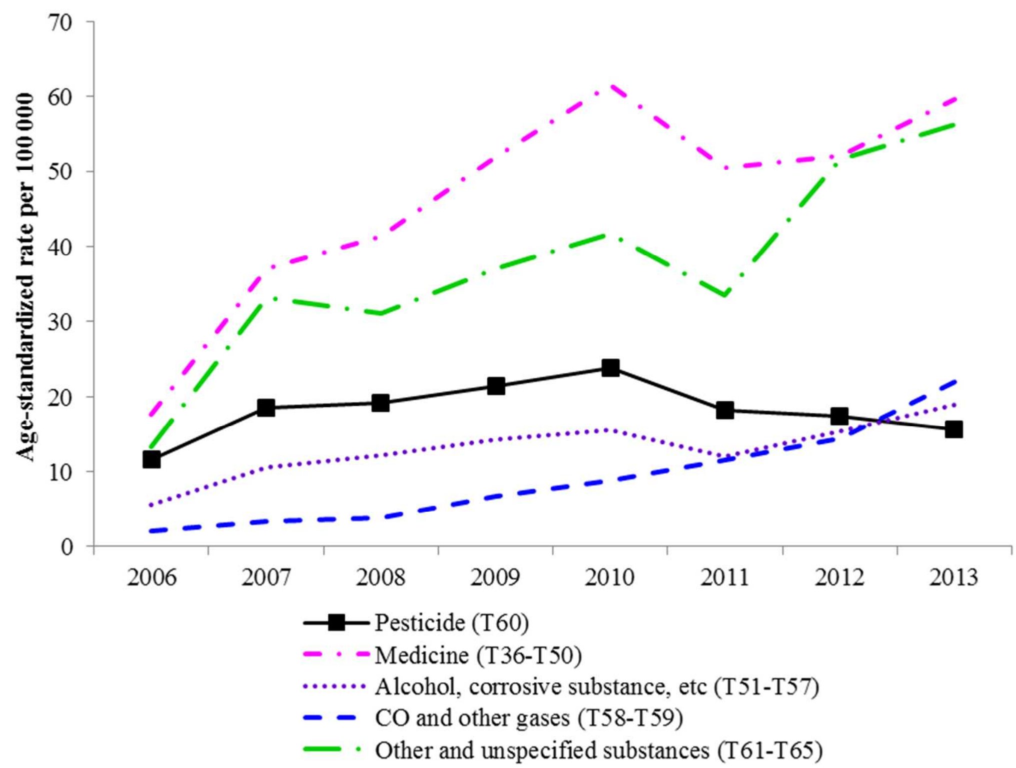

Cancellation of paraquat re-registration
Age-standardized rate per 100 000
10
9
8
7
6
5
4
3
2
1
0
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Pesticide suicide per 100 000
Predicted line based on trend 2003-2011

Figure 2

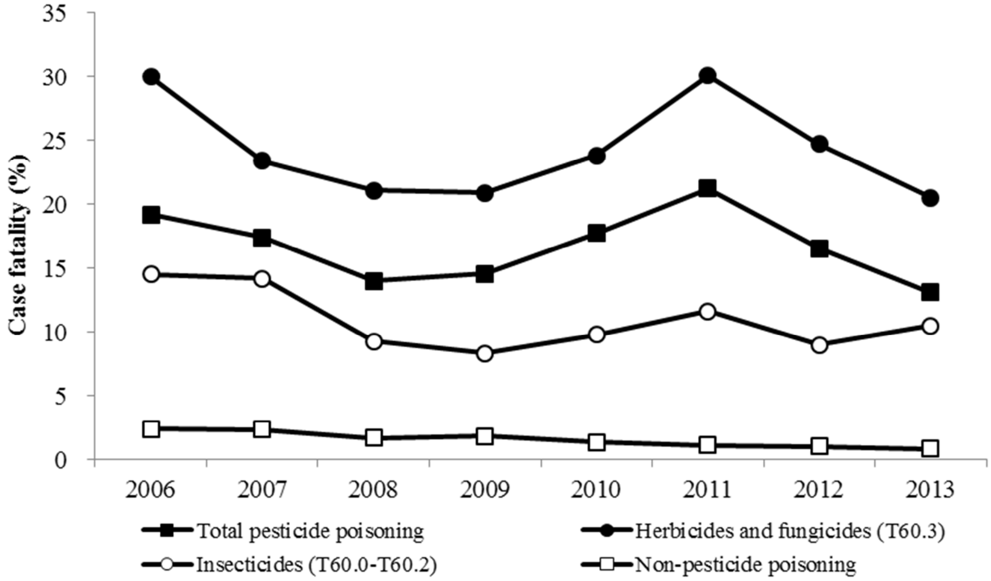
(a)


Age-standardized rate per 100 000
0
1
2
3
4
5
6
7
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Herbicides and fungicides (T60.3)
Insecticides (T60.0-T60.2)
Rodenticides and other pesticides (T60.4, T60.8)
Unspecified pesticides (T60.9)
Medicine (T36-T50)
Alcohol, corrosive substance, etc (T51-T57)
CO and other gases (T58-T59)
Other and unspecified substances (T61-T65)

(b)


Age-standardized rate per 100 000
0
10
20
30
40
50
60
70
2006
2007
2008
2009
2010
2011
2012
2013
Pesticide (T60)
Medicine (T36-T50)
Alcohol, corrosive substance, etc (T51-T57)
CO and other gases (T58-T59)
Other and unspecified substances (T61-T65)

(c)


35
30
25
20
15
10
5
0
Case fatality (%)
2006
2007
2008
2009
2010
2011
2012
2013
Total pesticide poisoning
Herbicides and fungicides (T60.3)
Insecticides (T60.0-T60.2)
Non-pesticide poisoning

Supplementary

Table 1S. Canceled pesticide products in South Korea, 1983-2013

No	Canceled pesticide product	Date of ban	Chemical category	WHO classification[a]
1	Maleic Hydrazide	1983	Unclassified	U
2	2,4,5-TP	1984	Chlorophenoxy	O
3	Quintozene	1987	Substituted Benzene	U
4	Maneb	1989	Dithiocarbamate	U
5	Chlorobenzilate	1989	Unclassified	O
6	Amitrol	1989	Unclassified	U
7	Cyhexatin	1989	Heavy metal, Organotin	II
8	Disulfoton	1989	Organophosphate	Ia
9	Zineb	1990	Dithiocarbamate	U
10	Carbophenothion	1990	Organophosphate	O
11	Propaphos	1990	Organophosphate	O
12	Parathion (47%)	15 May 1990	Organophosphate	Ia
13	Heptenophos	1991	Organophosphate	Ib
14	Dialifos	1991	Organophosphate	O
15	Thiometon	1991	Organophosphate	Ib
16	Aldicarb	28 June 1991	N-Methyl carbamate	Ia
17	Chlorfenvinphos	1992	Organophosphate	Ib
18	Captafol	31 March 1993	Thiophthalimide	Ia
19	Mecarbam	2001	Organophosphate	Ib
20	Methyl bromide+Chloropicrin	2001	Halogenated organic+Inorganic	Fumigant, not classified
21	Quinalphos	2001	Organophosphate	II
22	Oxolinic acid+Thiabendazole	11 December 2003	Unclassified+Benzimidazole	III
23	Dichlorvos+Phosalone	May 2005	Organophosphate	Ib+II
24	Parathion-ethyl (17%)	26 May 2008	Organophosphate	Ia
25	Bensulfuron-methyl+Molinate	26 May 2008	Sulfonylurea+Thiocarbamate	U+II
26	Triforine	26 May 2008	Unclassified	U
27	Quinalphos	26 May 2008	Organophosphate	II
28	Chlorpyrifos+Lambda-cyhalothrin	26 May 2008	Organophosphate+Pyrethroid	II
29	Bensulide	26 May 2008	Organophosphate	II
30	Difenoconazole	28 June 2008	Azole	II
31	Tebuconazole	28 June 2008	Azole	II
32	Napropamide	28 June 2008	Amide	U
33	All items containing molinate	01 July 2008	Thiocarbamate	II
34	Carpropamid+Edifenphos	03 March 2009	Unclassified+Organophosphate	U+Ib
35	Butachlor	11 March 2009	Chloroacetanilide	III
36	Demeton-S-methyl	07 April 2010	Organophosphate	Ib
37	Methamidophos	07 April 2010	Organophosphate	Ib
38	Triazophos	07 April 2010	Organophosphate	Ib
39	Diazinon+Fenobucarb	20 September 2010	Organophosphate+N-Methyl carbamate	II
40	Benfuracarb+Fenpropathrin	20 September 2010	Carbamate+Pyrethroid	II
41	Dicofol	13 December 2010	Organochlorine	II
42	Paraquat	23 November 2011	Bipyridylium	II
43	Dichlorvos	06 December 2011	Organophosphate	Ib
44	Endosulfan	06 December 2011	Organochlorine	II
45	Methidathion	06 December 2011	Organophosphate	Ib
46	Methomyl	06 December 2011	N-Methyl carbamate	Ib
47	EPN	06 December 2011	Organophosphate	Ia
48	Monocrotophos	06 December 2011	Organophosphate	Ib
49	Benfuracarb	06 December 2011	Carbamate	II
50	Omethoate	06 December 2011	Organophosphate	Ib
51	Tolylfluanid	18 April 2012	Unclassified	U
52	Tebuconazole+Tolylfluanid	18 April 2012	Azole	II+U
53	Dichlofluanid	18 April 2012	Unclassified	U
54	Deltamethrin+Dichlorvos	04 March 2013	Pyrethroid+Organophosphate	Ib+U
55	Propisochlor	04 March 2013	Chloroacetanilide	-
56	Tralomethrin	04 March 2013	Pyrethroid	II
57	Asulam-sodium	04 March 2013	Other carbamate	III

[a]The WHO recommended classification of pesticides by hazard. Ia: Extremely; Ib: Highly; II: Moderately; III: Slightly; U: Unclassified; O: Obsolete as pesticide, not classified

Table 2S. Joinpoint regression analysis: annual percent change (APC) and joinpoints (JP) for trends in age-standardized rate of pesticide suicide in South Korea, 1983-2013

	Segment 1 APC (95% CI[a])	JP1 (95% CI)	Segment 2 APC (95% CI)	JP2 (95% CI)	Segment 3 APC (95% CI)	JP3 (95% CI)	Segment4 APC (95% CI)	JP4 (95% CI)	Segment5 APC (95% CI)	JP5 (95% CI)	Segment6 APC (95% CI)
Pesticide suicide	-6.2 (-9.8, -2.3)	1991 (1985, 1994)	13.8 (-3.3, 34.0)	1995 (1988, 2002)	0.9 (-7.1, 9.5)	2000 (1998, 2005)	29.7 (4.8, 60.5)	2003 (2002, 2008)	-6.4 (-8.5, -4.2)	2011 (2008, 2011)	-27.3 (-42.4, -8.2)

[a]Confidence Interval

Table 3S. Rate ratios and change in number of pesticide suicides in 2013 relative to those expected based on trend 2004-2011 and 2002-2011 by selected characteristics

	Based on trend 2004-2011			Based on trend 2002-2011		
Characteristics	Rate ratio[a] (95% CI[b])	Change in number of pesticide suicides (95% CI[b])	*p* for interaction	Rate ratio[a] (95% CI[b])	Change in number of pesticide suicides (95% CI[b])	*p* for interaction
Total	0.62 (0.55, 0.70)	-884 (-1180, -618)		0.60 (0.51, 0.69)	-961 (-1385, -648)	
Gender						
Male	0.61 (0.53, 0.71)	-625 (-867, -399)	0.983	0.60 (0.49, 0.73)	-652 (-1018, -362)	0.980
Female	0.63 (0.55, 0.73)	-273 (-380, -172)		0.60 (0.50, 0.72)	-309 (-464, -180)	
Age group						
15-49	0.51 (0.40, 0.63)	-162 (-254, -99)	0.545	0.49 (0.38, 0.62)	-176 (-276, -104)	0.824
50-59	0.61 (0.50, 0.75)	-157 (-245, -82)		0.56 (0.44, 0.70)	-193 (-312, -105)	
60-69	0.53 (0.46, 0.61)	-231 (-305, -166)		0.46 (0.36, 0.59)	-305 (-462, -181)	
≥ 70	0.61 (0.54, 0.68)	-491 (-654, -361)		0.53 (0.44, 0.65)	-681 (-977, -414)	
Area						
Metropolis	0.60 (0.50, 0.72)	-145 (-218, -85)	0.099	0.57 (0.46, 0.69)	-164 (-256, -98)	0.199
Small- and medium-size city	0.69 (0.61, 0.79)	-342 (-487, -203)		0.65 (0.56, 0.76)	-410 (-599, -241)	
Rural	0.55 (0.47, 0.63)	-378 (-521, -271)		0.52 (0.44, 0.62)	-426 (-588, -283)	
Causative agents						
Herbicides and fungicides (T60.3)	0.52 (0.46, 0.58)	-823 (-1047, -646)	<0.001	0.50 (0.42, 0.59)	-892 (-1232, -620)	<0.001
Insecticides (T60.0-T60.2)	0.73 (0.59, 0.90)	-89 (-167, -27)		0.66 (0.53, 0.81)	-124 (-213, -56)	
Rodenticides and others (T60.4, T60.8)	1.73 (1.08, 2.75)	12 (2, 18)		1.00 (0.61, 1.63)	0 (-19, 11)	
Unspecified (T60.9)	0.91 (0.77, 1.07)	-28 (-84, 18)		0.87 (0.73, 1.03)	-42 (-104, 8)	
Season						
Spring	0.67 (0.59, 0.77)	-223 (-314, -135)	0.760	0.62 (0.53, 0.72)	-277 (-401, -176)	0.932
Summer	0.56 (0.48, 0.65)	-332 (-457, -227)		0.55 (0.46, 0.65)	-345 (-495, -227)	
Fall	0.59 (0.50, 0.70)	-213 (-307, -132)		0.57 (0.47, 0.68)	-232 (-346, -144)	
Winter	0.68 (0.58, 0.80)	-123 (-189, -65)		0.62 (0.52, 0.74)	-160 (-241, -92)	

[a]Adjusted for age, gender and calendar year
[b]Confidence Interval

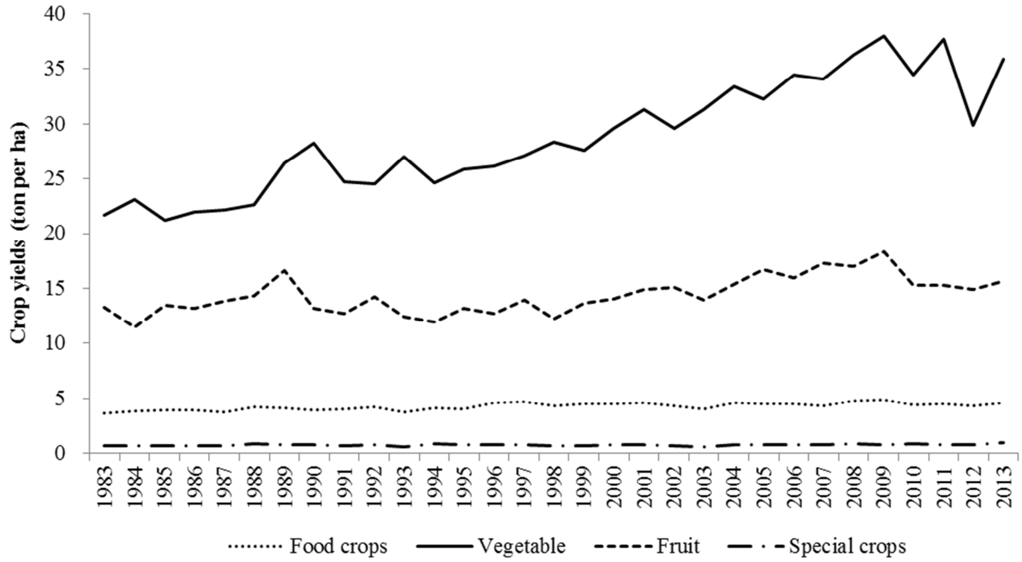


Figure 1S. Agricultural crop yields by type of crops in South Korea, 1983-2013

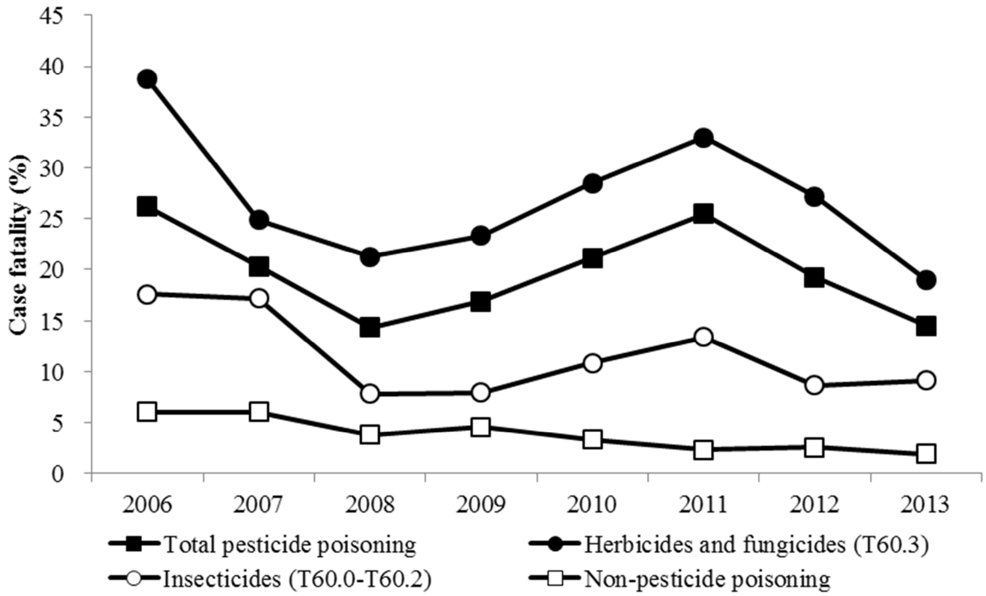


Figure 2S. Case fatality proportion for intentional poisoning by pesticide and non-pesticide in South Korea, 2006–2013